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THE GASES OF DECAY AND THE HARM THEY CAUSE IN DWELLINGS AND POPULOUS PLACES.

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In these latter days so much has been said about the gases of decay and their relations to health and disease, that I can hardly hope to add anything absolutely new. I only hope to call attention to some chemical phases of the subject which I think important to keep in mind in the practical treatment of the sanitary questions they relate to, and to make these the hooks upon which to hang a few questions about the best methods of ventilating sewers.

What chemists call "organic" substances, in nature, are all the products of life, directly or indirectly. They are vast in number, and of wonderful variety of character and composition, agreeing only in this, that they all contain carbon combined with oxygen, nitrogen, or hydrogen, sometimes with other elements, of which only sulphur and phosphorus, or, indeed, only sulphur, need here be considered. All organisms, unless of the very lowest forms, are built of a considerable number of complicated chemical compounds, which, when brought under other conditions than those which produced them, have a tendency to decompose, and, if the conditions are favorable, to be resolved again into their original elements, or else, into certain simpler compounds which are called "minerals." Now, this decomposition in nature we call *decay*, and in its sanitary relations it may be considered in two stages: —

1st. The more complex chemical combinations break up into those of simpler formulas by a rearrangement of the molecules.

2d. All these resulting compounds ultimately return to their elementary condition, or to oxides.

If the original organic compound or organism contained much nitrogen, and the right conditions of moisture and temperature exist, we have what is called putrefaction and stinking gases are evolved, — the term putrefaction being a popular term rather than a scientific one. The stinking gases are without doubt mostly organic compounds, and may be destroyed by oxidation or further decomposition. In nearly every stage of the process, there are resulting compounds which may be the food of new organisms, animal and vegetable, particularly the latter, some of which act in such a way as to hasten the change, as in the case of ferments and many fungi. Others simply use such compounds as food, without otherwise affecting the source of it. In either case, the natural decay is arrested or modified so far as the

compounds which are used by the new beings are concerned. When not thus arrested, the process goes on until the mineral matter is returned to its original "dust" and the remainder into gases. This last is, indeed, very much the larger portion. The ultimate products are comparatively few; but, during the process, many compounds are produced, some of which are gases, — the gaseous mixtures being complicated ones, — and the experience of ages has shown that some of these gases or their mixtures are hurtful to health.

In a comparatively few cases we can see a chemical reason for this, but in a vast number we have the fact while the process is yet secret. A few of the gases of decay are well known to chemists; they have been isolated; we are familiar with their properties, but they are mostly those gases formed in the later stages. Carbonic acid, ammonia, marsh gas, sulphureted hydrogen, nitrogen, possibly carbonic oxide; these are all well enough known, two at least are disagreeable to the smell, and some of them are harmful to the health if present in the air in any considerable quantities. Neither of these produce the diseases prominently associated with filth gases; they certainly do not generate such diseases, nor is it proved that they are especial carriers of their germs; nor indeed do they specially aggravate the symptoms of such diseases more than any other unwholesome condition does. Morever, it is not proved that any or all the gases I have mentioned (unless it be sulphureted hydrogen) occur in our houses in sufficient quantities to be very hurtful except in rare cases. I use the old and well known names for the gases rather than the new ones, most of us being more familiar with the term carbonic acid than with carbonic dioxide, and so of the others.

Regarding sulphureted hydrogen, we know that it is poisonous, and its action on arterial blood is a common lecture-table experiment. Yet I cannot but think that its unhealthiness is overrated; we may perceive it often in the analytical laboratory, or in the neighborhood of a sulphur spring, vastly ranker than I have ever smelled it in a sewer or privy, yet the persons subjected to it do not usually suffer any considerable inconvenience. Carbonic acid is the most abundant, and is poisonous; yet when diluted seems not to be very hurtful, if generated from other than decaying substances, as about lime-kilns and furnaces. Its great interest and importance to the sanitarian is mostly in the fact that in certain investigations, such as the determination of the impurity of the air in assembly-rooms, it is the measure of other impurities. In such cases, its proportion in the air can easily be determined exactly, while the more subtle and more hurtful accompaniments cannot be so measured. A candle in a room may consume as much oxygen, and generate as much carbonic acid, as a person; yet no one claims or believes that one man and a hundred such lighted candles in a room would make the air as unwholesome as would a hundred persons and one candle. Carbonic acid is not wholesome, but it is not the worst element in the air of a crowded room, or of the gas that escapes from a sewer or cesspool. The nitrogen contained in the original organism is, perhaps, largely resolved into ammonia, this in turn to be ultimately oxidized. As a

product of decay, ammonia is, perhaps, always in the milder form of carbonate, and only in the rarest of cases abundant enough to be especially hurtful. Where oxygen and nitrogen, as such, exist, whatever be their source, they are not poisonous; surely oxygen is not, and nitrogen is inert and negative, not positively poisonous. Phosphureted hydrogen is often spoken of as one of the products in the decomposition of animal matter, and we have stories of the will-o'-the-wisp as an alleged proof of its occurrence. I have sometimes thought I could perceive its peculiar odor in the rank stench of small animals rapidly decaying in hot weather. It is affirmed that animals or fish, rotting under water or in mud, generate it, and that it is one cause of the unwholesomeness of such exhalations. It seems to me very questionable if it is produced under ordinary, if, indeed, under any conditions in nature. With another chemist some years ago I conducted a long and careful investigation of the gases generated by fish decaying under water, one of the objects of which was to test this very matter. We failed to find even a trace of phosphureted hydrogen by the most refined tests then known. Marsh gas, or light carbonated hydrogen, is one of the products of decay under certain conditions. Inasmuch as it is known to be generated in swamps and shallow water with decaying matter at the bottom, the hypothesis is often put forth that it is an ingredient in, or even the cause of malaria. I need not say that this is mere conjecture; there is not a particle of proof, and no such effects follow the breathing of this gas when generated in the processes of the arts. If carbonic oxide is ever generated in decay, it is only under very peculiar conditions and in infinitesimal quantities, and may be disregarded in this connection.

We have now exhausted the list of gases known to chemists as being generated in the ordinary processes of decay, and none of them seem capable of producing the effects that *sewer gas* is known to produce. This last seldom gets into our houses in sufficient quantities to materially diminish the relative amount of oxygen, or to poison with carbonic acid; yet its results are not negative; it acts as a poison, and the physiological effects are unlike those which follow the breathing of any of the definite gases I have named, even of such as are known to be poisonous.

If the physiological effects which follow the breathing of sewer gas so called, are produced by actual gases, acting chemically, then these gases are absolutely unknown to chemists, and exist in too small quantities to be estimated by any known process of gas analysis. This, however, is no proof that they do not exist. The sense of smell tells us that there are organic gases and compounds never yet isolated, and of whose composition and properties, other than their smell, we are entirely ignorant. Indeed, we are ignorant of the composition of most of the *smells* of putrescent matter. In the investigation of the gases from rotting fish, of which I have spoken, the gases were very stinking, intensely so; yet the actual amount of the gas which had the odor was too small to be detected by the ordinary means of gas analysis, and these analyses were conducted under the eye, and some of them with the aid, of Prof. Von Bunsen, then, as now, the most eminent gas analyst in the world. The analyses of sewer

gases point in the same direction. The result of some experiments on the air of sewers and drains are given in the Report of the British Association Sewage Committee, 1869–70. Specimens were collected from various street and house sewers, chiefly in the Paddington District, and during August, so that there is every probability of the air being as foul as possible. They were chemically examined by Dr. W. J. Russell. The most impure air contained only half a per cent. of carbonic acid; the remainder was oxygen and nitrogen, so far as discovered by analysis. Another, "with a foul smell," contained only one eighth of one per cent. of carbonic acid. There were "no combustible gases." In their investigation, they found only traces of ammonia, and often no sulphureted hydrogen. It is needless to multiply cases. It is not, of course, denied that sewer gases have been found so concentrated and foul as to produce suffocation; but very bad effects are well known often to follow the admission of such minute quantities into our houses that they can barely be perceived, much less suffocate. That it lowers the tone of health, and sometimes produces active disease in those who are subjected to it, is too well known to admit of a doubt. So far as this first effect occurs, lowering the tone of health, we can easily imagine it to be produced by *chemical* causes. Definite physiological results are known to follow the absorption into the system of definite chemical compounds. The effect of medicines and of poisons are illustrations too common to need more than a reference to them. The agent may work speedily, as in the case of active poisons, or slowly as in the case of cumulative ones. The effects may be gentle, as with certain tonics, or violent; and, as in arsenic poisoning, take a somewhat definite time, like a fever running its course; but in all poisoning by chemical means, the physiological effect is largely proportional to the amount of the chemical used, and the effects cease with the victim. Moreover, the results are reasonably uniform.

This is very unlike the effects believed to be caused by sewer gas, or other filth gases, where the results are by no means uniform, nor do they appear to be at all proportionate to the amount of the gas breathed, nor its degree of concentration. More than this, the results do not stop with the victim. Typhoid fever once started may extend, we know not to how many other victims, if the right conditions exist to carry it. And this brings us face to face with that mooted subject, the *Germ* theory of zymotic diseases, a theory now generally accepted by chemists, but strongly combated by some of the most eminent microscopists and physiologists.

That typhoid fever has been caused by the escape of gases from sewers and cesspools into houses, seems to me to be proven beyond a reasonable doubt. For illustration, — in the now famous town of Croydon, special cases are mentioned (9th Report Medical Officer of the Privy Council, 104) where the disease is alleged to have been distinctly traced to this cause. The gas was known to have been driven into the house; it "did not smell offensively, only a faint, sickly odor being recognized." In this case, the gas was driven into the house by a shower filling the conductors with water; other cases at the same time are believed to be traceable to the same source. The odor was generally not rank, "a faint odor alone being recog-

nized." I think it is generally conceded that typhoid, once started, may be propagated from patient to patient through the medium of the evacuations. Now, all this is unlike the operation of any known chemical compound, gaseous or otherwise. Again (from the same Report) the outbreak of cholera in the City of London Union Workhouse, in 1866, investigated by Mr. Radcliffe, was shown to have taken place, in all probability, from a sudden efflux of "sewer air from a drain containing choleraic evacuations," this efflux being caused, or at least favored, by a sudden change of atmospheric temperature and pressure. Here, again, the gas, or "sewer air," spoken of as the agent, is not necessarily a "gas of decay;" yet, if a gas at all, it must have been an organic gas, acting as a poison, but how unlike all actual chemical poison where the agent is a known chemical compound.

Again, decay of filth in the dark and away from free access of air is supposed to be productive of gases especially dangerous, more so than when decay goes on in the light and free air, and moreover that sewer gas is rendered less hurtful by a free circulation of air within the sewers. That this last is not due to mere dilution is shown by the deleterious character of the gas when diluted only after it enters the houses.

Considered purely as a chemical question, these facts, if facts, are entirely inexplicable. If the germ theory is accepted, a plausible explanation is more easy. It is possible to imagine a condition of things in decaying organic *gases* similar to that which occurs in decaying organic *infusions*. It is universally known that such infusions soon swarm with minute organisms; in fact, their almost universal occurrence in such connection gave these organisms the general name of "*infusoria*," and different forms are generated according to the different chemical characters of the infusion. The changing organic compounds in the fluid are doubtless the food by which these low organisms are nourished. Certain specific forms thrive best in certain definite infusions, and appear there when given proper temperature, and once started they increase and multiply as do other organisms. Now it is easy to imagine an analogous state of affairs in decaying organic gases. Moisture is always an element in these unwholesome gases of decay, and along with it are some gases that are organic, generated by the breaking up of the more complex molecules. Their quantity may be small compared with the whole volume of gas with which they are mixed, and yet sufficient to nourish floating organisms, just as a mere trace of solid matter, dissolved in much water, making a very weak infusion, is often nutritious enough to support its swarms of infusoria. If this be the case, it may possibly explain the anomaly that dilution of gas with air within the sewer renders it comparatively harmless, while it may be very poisonous if it is diluted only after it enters our houses. If the analogy is good, that floating organisms which may be the germs of disease feed on and multiply in the decaying organic gases of sewers, as infusoria feed on and multiply in infusions when the temperature and degree of concentration are favorable, then such floating organisms, after having been produced in the sewer and then admitted into the house, would not be destroyed by dilution of the gases in which they float; while, on the other hand, proper dilution in the sewer might by oxi-

dation or in other ways prevent their generation, or at least so impair the conditions that they cannot multiply in harmful numbers.

The belief that malaria is related in some way to the gases of decay, has already been referred to. That it is often so associated in moist air, is well enough known. The draining of swamps and giving the air access to the vegetable mud accumulated in such places, the clearing of land and consequent rapid decay of accumulated leaf-mold, have often been related to the existence or spread of malarial diseases. Even the decaying leaves of our shade trees in the streets are often accused of adding to the malaria of a region. In these cases the decay goes on in free air and light, and the gases are diluted to the last degree as soon as liberated from the generating mass. Yet, here too, we can understand how organic gases may be concentrated enough, before being poured forth into the atmosphere, to give the requisite nourishment to the organisms or "germs." Such decaying vegetable matter is very porous; it contains air as a sponge may water, and this air, permeating the decaying substance, cannot be otherwise than highly charged with the product of decay, ready to be driven out in several ways. Take rotten wood as an example. The measure of its porosity is seen in the difference of weight when wet and dry. A little experiment, tried for another purpose the present week, may be used as illustration. A few days ago, where some workmen were repairing the wooden pavement in one of the streets of our city, I picked up a few pieces of the half rotten wooden blocks. They were saturated with the water of the recent rains. Two pieces weighed, as they came wet from the pavement, respectively, 287 and 130½ grams. They were then left on the table in my study four days and then yesterday weighed again; they were not nearly dry, yet they weighed respectively only 154 and 54½ grams. That is, as thus dried, one will absorb 86 per cent., the other (and most decayed) 139 per cent., water, before saturation. It is easy to see how much foul air in a concentrated form a wooden pavement, half rotten, may hold, to be driven out by the first shower, or any other cause that disturbs the equilibrium of the atmosphere.

I did not intend to say so much of this germ-hypothesis, but have been led to it by looking at the chemical side of our inquiry. We are discussing the subject of better ventilating the sewers of our city. I have been trying to get light on this rather new problem, new at least with us; and the more studied, the more necessary seems to me such ventilation, even on purely theoretical grounds. If the chemical hypothesis of poisonous gases be the correct one, then, by perfect ventilation, we secure more speedy oxidation and get those ultimate gases which it is known do not produce the active diseases which we believe to be due to sewer gases. If, on the other hand, we accept the germ-hypothesis — that such diseases are caused by specific organisms — then by ventilation we may impair the conditions which produce such organisms or under which they multiply.